PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04R 7/10, 19/02

A1

(11) International Publication Number: WO 99/56498

(43) International Publication Date: 4 November 1999 (04.11.99)

(21) International Application Number: PCT/FI99/00337

(22) International Filing Date: 26 April 1999 (26.04.99)

(30) Priority Data:
980926 27 April 1998 (27.04.98) FI

(71) Applicant *(for all designated States except US)*: PANPHONICS OY [FI/FI]; Pyhäjärvenkatu 5 B, FIN-33200 Tampere (FI).

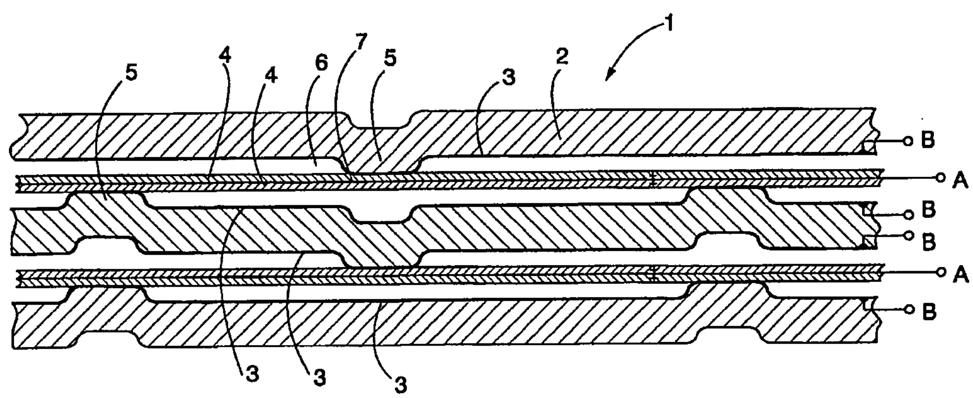
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: KIRJAVAINEN, Kari [FI/FI]; Kivenlahdenkatu 11 A 4, FIN-02320 Espoo (FI).

(74) Agent: KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).

(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: ACOUSTIC ELEMENT



(57) Abstract

The invention relates to an acoustic element comprising and arbitrary number of layers. Each layer comprises at least one porous layer (2) and a film (4) arranged at a distance from the layer. The porous layer (2) can be electrically conductive or coated at least on one of its surfaces to be electrically conductive, and the film (4) can be charged or provided with at least one electrically conductive surface. The porous layer (2) and the film (4) come into contact with each other substantially only at support points (5). The support points (5) are arranged so as to allow the entire structure to change its thickness.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

ACOUSTIC ELEMENT

The invention relates to an acoustic element which comprises an arbitrary number of layers, at least one layer comprising at least one porous layer which is either electrically conductive or coated at least on one of its surfaces to be electrically conductive, and at least one film, which is either charged or provided with at least one electrically conductive surface, at least one porous layer and film being arranged to come into contact with each other substantially only at support points, thereby providing an air gap between the porous layer and the film.

WO publication 97/31506 discloses a plate-like acoustic element comprising fixed stator plates, with a film secured between the plates at predetermined support points. Between the stator plate and the film are left small air gaps that allow the film 3 to move. The stator plates and the film are provided with electrically conductive surfaces, so by applying electric signals to the surfaces, the film 3 can be made to move to produce sound. The structure is simple and has a very even frequency response, but its field of application is somewhat limited and, to produce a sufficiently high air pressure by using a moving film, a fairly strong electric field is required.

An object of the present invention is to provide an acoustic element allowing the above shortcomings to be avoided.

The acoustic element of the invention is characterized in that the support points are arranged in such a way that the acoustic element can change its thickness substantially entirely.

An essential idea of the invention is that the acoustic element comprises an arbitrary number of layers, at least one layer comprising a porous layer and a film arranged at a distance from the layer, the porous layer and the film coming into contact with each other substantially only at specific support points. The porous layer is either electrically conductive or coated at least on one of its surfaces to be electrically conductive, and the film is charged or provided with at least one electrically conductive surface. The support points at which the film and the porous layer come into contact with each other are arranged in such a way that the entire structure can change its thickness. A preferred embodiment is based on the idea that the acoustic element is coated with an elastic surface material. Another preferred embodiment is based on the idea that the acoustic element is hermetically

sealed.

An advantage of the invention is that the structure of the acoustic element is very light, solid, inexpensive and easy to manufacture. Further, because the gap between the porous layer and the film is fairly small, a reasonably high pressure is obtained by applying a fairly low control voltage. The porous material provides the element with a large air capacity, whereby the air displaced by the film is able to enter the porous layer, which reduces counter pressure and increases movement. The air entering the porous layer causes flow losses and therefore the structure does not resonate strongly. Further, due to the flow losses the material of the element also attenuates sound passively. An element coated with an elastic surface material can be used for a number of different applications (e.g. floors). Hermetic sealing of the element allows it to be used also in fairly humid conditions.

The invention will be described in greater detail in the accompanying drawings, of which

Figure 1 is a schematic sectional side view of an acoustic element of the invention;

Figure 2 is a schematic sectional side view of another acoustic element of the invention; and

Figure 3 is a schematic view of a third embodiment of the invention.

Figure 1 shows an acoustic element 1 comprising a plural number of porous layers 2. A typical porous layer is, for example, 0.5 to 1mm thick, about 70% of the layer being air. The porous layer 2 can be made of cellulose, glass fibre, mineral fibre, metal fibre or by sintering plastic or metal powder. The porous layer 2 is either electrically conductive or coated at least on one of its surfaces to be electrically conductive, for example, by sputtering the surface to provide a metallization 3 thereon. The metallization 3 of the porous layer 2 is typically about 40 nanometers thick. The metallization 3 on the porous layer 2 is also porous in order to allow air to pass through the porous layer 2 and the metallization 3.

The acoustic element 1 further comprises a film 4 arranged between the porous layers 2. The porous layer 2 and the film 4 come into contact with each other only at support points 5, an air gap 6 being thus formed between the porous layer 2 and the film 4. The thickness of the film 4 is typically about 5 micrometers and the width of the air gap 6, correspondingly, about 10 micrometers.

Figure 1 shows an embodiment in which two films 4 are arranged one on the other, a metallization 7 typically about 40 nanometers thick being arranged between the films. The films are charged and they can be made of polypropylene, polymethyl pentene or cyclic olefin copolymer, for example. The films 4 can be further provided with a bubble structure comprising flat bubbles.

Porous layers 2 and films 4 are arranged one on the other to provide the acoustic element 1 with a layered structure as shown in Figure 1. Control electrodes A are connected to the metallizations 7 between the films 4 and earth electrodes B, correspondingly, to the metallizations 3 of the porous layers 2. The support points 5 are arranged in such a way that the film 4 is not supported to the porous layers 2 at exactly the same points on opposite sides of the film. Consequently, when a signal is supplied to the control electrode A, the film 4 changes is form. Since the film 4 is secured to the porous layer 2 at the support point 5, the porous layer 2 also moves and, since the support points 5 are at different places in the acoustic element, the acoustic element 1 can change its thickness substantially entirely.

Pressure P caused by the acoustic element 1 is obtained from the following formula

$$P = ½ * \frac{\varepsilon * U^2}{s^2},$$

where s is the width of the air gap 6,
U is voltage acting over the air gap 6, and
ε is a dielectricity constant of an intermediate medium.

Since the width s of the air gap 6 in the element concerned is very small, the voltage U need not be very high to provide a fairly high pressure P.

Figure 2 shows an acoustic element with a plural number of different layers arranged one on the other. In the embodiment shown in Figure 2 one side of the film 4 is secured substantially entirely to a first porous layer 2. The other side of the film 4 is secured to a second porous layer 2 substantially only at support points 5, between the second porous layer 2 and the film 4 being then the air gap 6. When the film 4 moves, it also makes the porous layer 2 move to which it is secured. The support points 5 of successive

air gaps 6 are at different places, thereby allowing the entire acoustic element to change its thickness.

The support points 5 can be formed on the porous plates 2, for example, by pressing the plates at suitable places to form bulges. The places of the support points 5 can vary symmetrically or randomly, but it is essential that the support points 5 of successive layers are arranged at substantially different places.

A strong electric field reduces the elastic constant of the structure, i.e. due to pressure the thickness of the structure changes essentially more than without the electric field, thereby substantially increasing the attenuating capability of the structure and lowering its resonance frequency. When the control electrodes A and the earth electrodes B are connected with each other, the structure can function in an attenuating manner, control electronics being not needed then. Between the control electrodes A and earth electrodes B can also be applied a static pre-voltage which allows the elastic constant of the structure to be controlled in a desired manner. The films 4 can also be provided with a permanent electret charge, if desired. The pre-voltage can be applied through a resistor having a high resistance, or the control electrode A, for example, can have a high resistance.

Figure 3 illustrates the acoustic element 1 coated with an elastic surface material 8. The thickness of the surface material 8 can be from 0.1 to 10mm, for example. The surface material 8 can be a rubber carpet, for example, the acoustic element 1 thus being applicable as a floor covering, for example. The edges of the acoustic element can be provided with sealing portions 9 to make the element 1 hermetically sealed. Also the control electronics 10 can be arranged inside the acoustic element. The hermetically sealed element 1 can be used in very demanding humid conditions. Further, the acoustic element 1 can be made into a preformed structural board, thereby allowing it to be used as a construction element. The surface material 8 can be substantially air impermeable because the entire acoustic element 1 can change its form and thereby produce sound, although it does not allow air to pass through. The acoustic element in question can be used, for example, for sound attenuating purposes (as floor mats in cars, for example). By increasing the mass of the surface material 8, the attenuating capability of the acoustic element 1 can be enhanced and the resonance frequency further lowered.

The drawings and the related description are only meant to illustrate

the inventive idea. The details of the invention may vary within the scope of the claims. The acoustic element 1 may comprise an arbitrary number of layers. To produce sound, at least one porous layer 2 and at least one film 4 are needed. Instead of two charged films 4 and the metallization 7 between them shown in the embodiment of Figure 1, a film with polarized charging can be used (i.e. a film having a positive charging on one side and a negative charging on the other), the control voltage being then applied between the surfaces of the porous layers 2. The film 4 does not have to be charged if at least its surface is electrically conductive. The acoustic element of the invention can be used in various applications relating to sound reproduction and active noise attenuation. The acoustic element, or some of its layers, can be used for example as sensors in acoustic systems while, at the same time, the other layers can be used as actuators.

CLAIMS

1. An acoustic element which comprises an arbitrary number of layers, at least one layer comprising at least one porous layer (2) which is either electrically conductive or coated at least on one of its surfaces to be electrically conductive, and at least one film (4), which is either charged or provided with at least one electrically conductive surface, at least one porous layer (2) and film (4) being arranged to come into contact with each other substantially only at support points (5), thereby providing an air gap between the porous layer (2) and the film (4), **characterized** in that the support points (5) are arranged in such a way that the acoustic element (1) can change its thickness substantially entirely.

2. An acoustic element according to claim 1, **characterized** in that the element (1) comprises at least two porous elements (2), at least one film (4) being arranged between the layers in such a way that on both sides of the film (4), an air gap (6) is formed, the support points (5) on opposite sides of the film (4) being arranged at substantially different places.

3. An acoustic element according to claim 1, **characterized** in that the element (1) comprises at least two porous layers (2), at least one film (4) being arranged between the layers in such a way that the film (4) is secured to a second porous layer (2) and between the second porous layer (2) and the film (4) is an air gap (6).

4. An acoustic element according to claim 3, **characterized** in that the acoustic element (1) is a layered structure comprising at least two air gaps (6) arranged one on the other, the support points (5) in successive air gaps (6) being substantially at different places.

5. An acoustic element according to any one of preceding claims, **characterized** in that the acoustic element (1) is coated with an elastic surface material (8).

6. An acoustic element according to claim 5, **characterized** in that the acoustic element (1) is hermetically sealed.

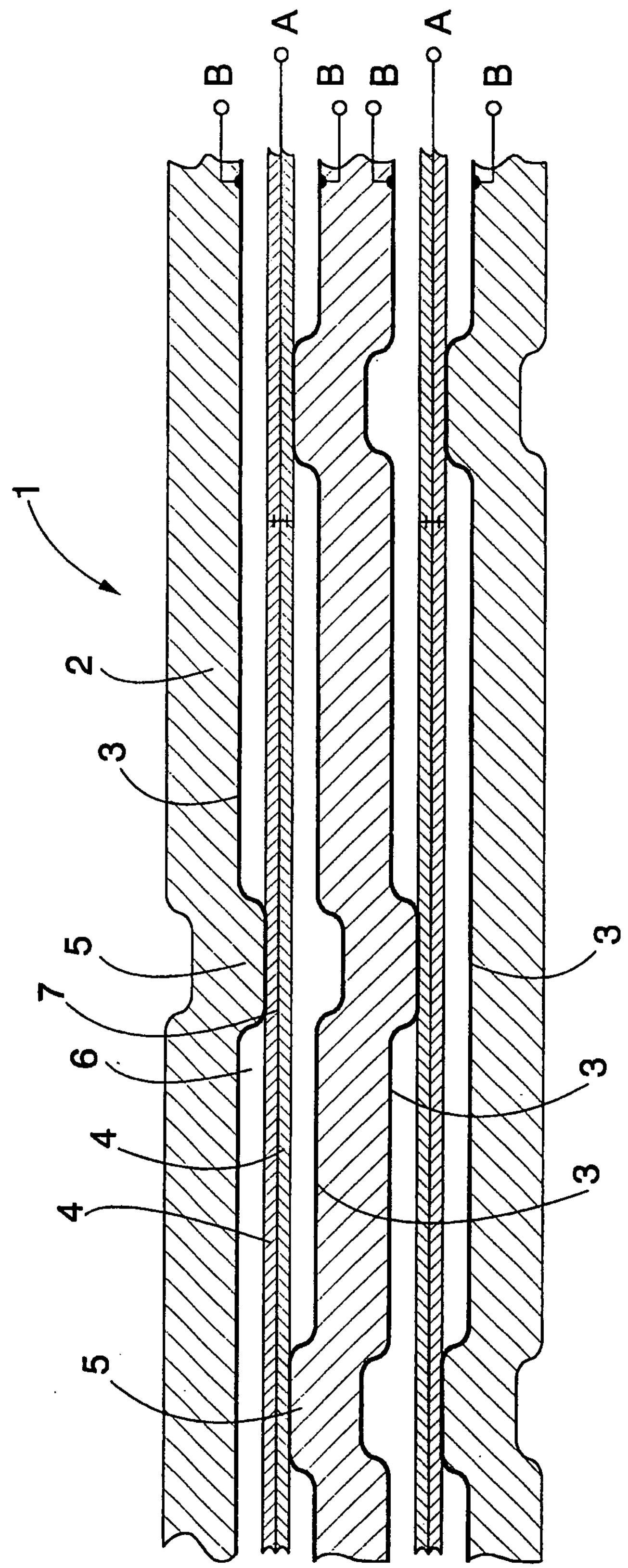


FIG. 1

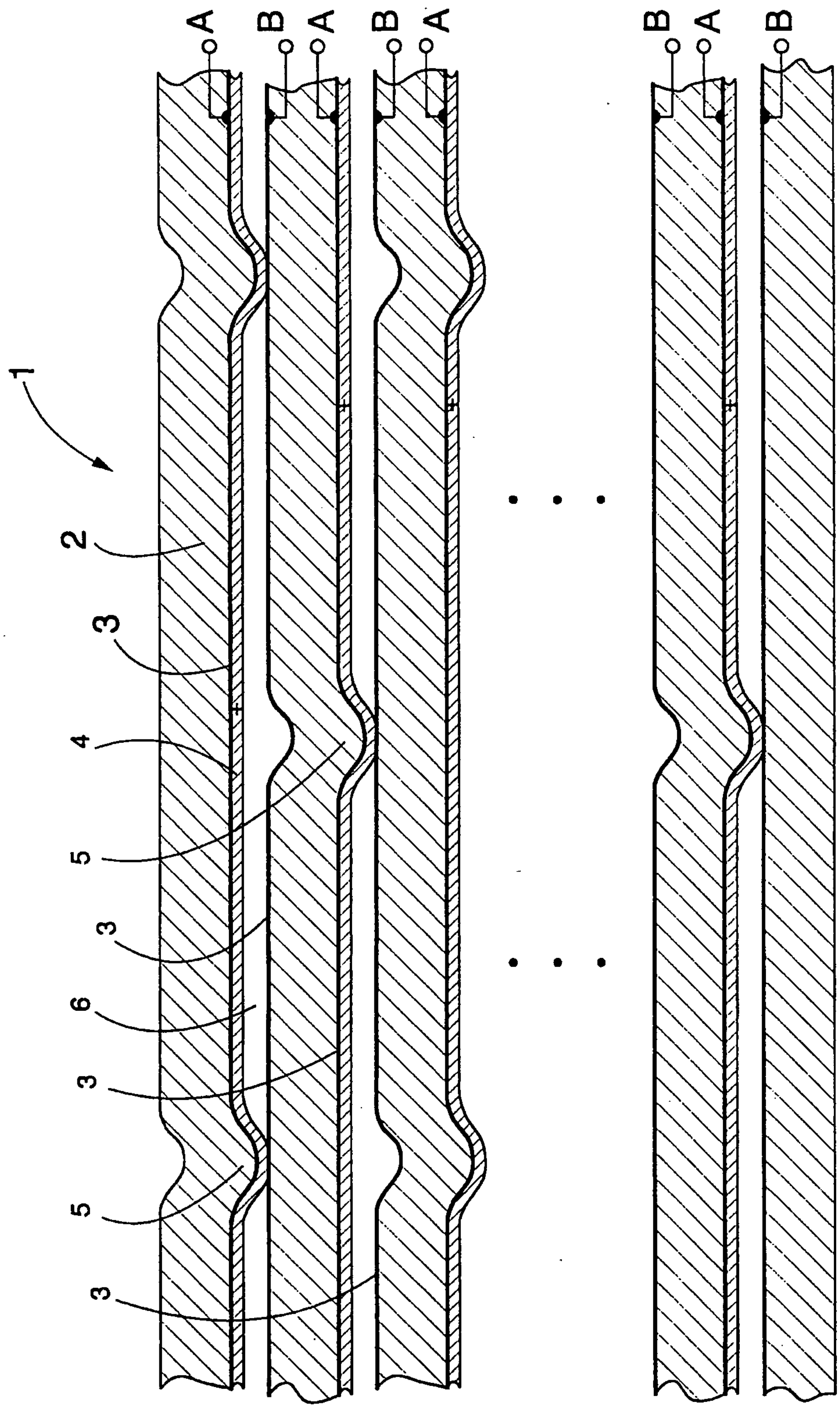


FIG. 2

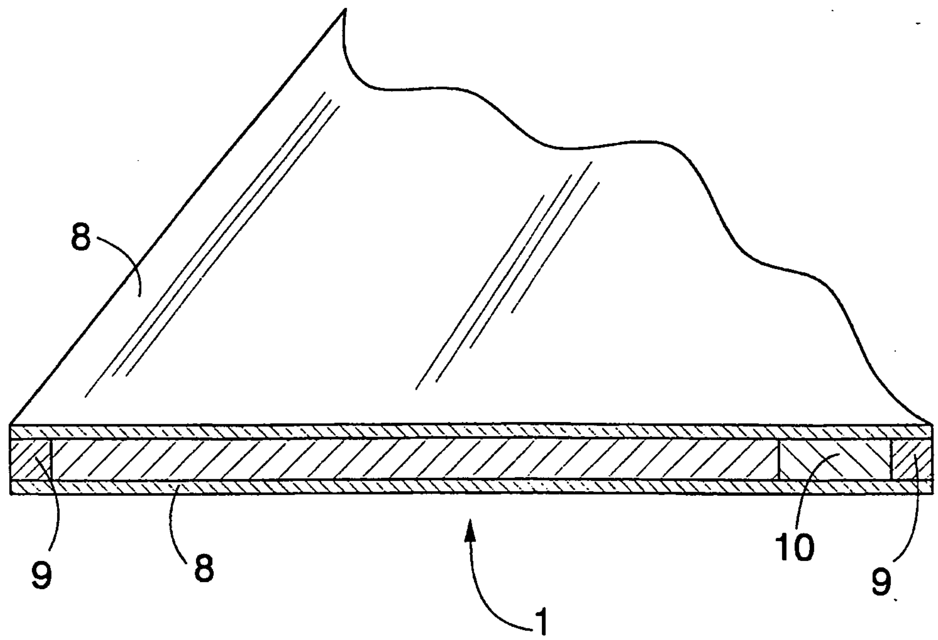


FIG. 3